# NACA

# RESEARCH MEMORANDUM

PERFORMANCE INVESTIGATION OF CAN-TYPE COMBUSTOR

I - INSTRUMENTATION, ALTITUDE OPERATIONAL LIMITS

AND COMBUSTION EFFICIENCY

By Eugene V. Zettle and William P. Cook

Flight Propulsion Research Laboratory
Cleveland, Ohio

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I - INSTRUMENTATION, ALTITUDE OPERATIONAL LIMITS

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SUMMARY

A brief investigation of the performance of a single can-type combustor designed for a turbojet engine having a military rating of 4000 pounds thrust at a rotor speed of 7700 rpm and equipped with an 11-stage axial-flow compressor and a single-stage turbine has been made. The investigation was conducted to determine: (a) the altitude operational limits of the engine for two fuels (AN-F-32 and AN-F-28), (b) combustion efficiencies at various simulated conditions of altitude and engine speed, (c) combustor-outlet temperature distribution for several altitudes at constant engine speed, and (d) the combustor total-pressure drop.

The limits with AN-F-32 fuel were found to be approximately 60,000 feet for an engine speed of 6000 rpm and approximately 38,000 feet for an engine speed of 4000 rpm. The results indicated that the altitude operational limits with AN-F-32 fuel are higher over the largest part of the engine-speed range than with AN-F-28 fuel. A combustion efficiency of 95 percent was obtained at rated engine speed (7600 rpm) and an altitude of 20,000 feet with AN-F-32 fuel. A change in altitude from 20,000 to 60,000 feet showed a 20-percent decrease in combustion efficiency while the engine was operating at 7600 rpm; whereas, at an engine speed of 4000 rpm a change of altitude from 10,000 to 40,000 feet showed a 52-percent decrease in combustion efficiency.

INTRODUCTION

The combustion processes in jet-propulsion engines are adversely affected by increased altitudes. For any given engine speed, there will be a certain altitude above which the engine will become limited because of combustion difficulties, that is, the engine will not

operate under those conditions of engine speed and altitude that
impose combustion difficulties. The combustor-design characteristics
largely determine these limitations for any given engine. It is
therefore of interest to know, for any given engine, the altitudes
at which the engine will be limited because of combustion difficulties
over its entire speed range.

The altitude operational limits of a single can-type combustor
designed for a turbojet engine having a military rating of 4000 pounds
thrust at a rotor speed of 7700 rpm and equipped with an 11-stage
axial-flow compressor and a single-stage turbine were obtained at
the NACA Cleveland laboratory. The altitude operational limits of
this combustor were obtained for two fuels, AN-F-32 and AN-F-28.
The combustion efficiencies at various simulated conditions of altitude
and engine speed, the combustor-outlet temperature-distribution plots
for several altitudes, and a combustor pressure-drop correlation are
also presented.

## APPARATUS AND INSTRUMENTATION

The combustor was connected to the laboratory-air supply, as
diagrammatically shown in figure 1. Air quantity and pressure were
regulated by remote-control valves upstream and downstream of the
combustor. The desired inlet-air temperature was obtained by the
use of an electric air preheater, which was automatically regulated
to maintain a constant inlet-air temperature.

The combustor-inlet section and the combustor itself were fur-
nished by the manufacturer. The combustor-outlet section, which was
fabricated at the Cleveland laboratory, duplicates that of a standard
contemporary engine using a can-type combustor. Two observation
windows axially located along the combustor made possible the visual
observation of combustion characteristics.

The number and location of instruments at the instrumentation
planes shown in figure 1 are tabulated as follows:

| Type of instrument | Number of instruments | | | |
|---|---|---|---|---|
| | Instrumentation plane | | | |
| | A | B | C | D |
| One-thermocouple rake | 2 | --- | --- | 3 |
| Three-tube total-pressure rake | 3 | --- | --- | --- |
| Five-tube total-pressure rake | --- | --- | 7 | --- |
| Five-thermocouple rake | --- | 7 | --- | --- |
| Static-pressure orifice connection | 1 | 1 | 1 | 1 |

All measurements were taken at the center of equal areas. Locations of the points of measurement at the respective instrumentation planes are shown in figure 2 and the instrumentation details are shown in figure 3. Temperatures were indicated by self-balancing potentiometers; air flow was measured by A.S.M.E. square-edge orifices and fuel flow by a rotameter. All instruments were calibrated. No attempt was made to correct the thermocouple readings for stagnation effects. A photograph of the combustor and instrumentation is shown in figure 4.

## METHODS

Experiments were conducted on the combustor covering a range of simulated altitudes from 10,000 to 60,000 feet and simulated engine speeds from 3500 to 7600 rpm. Combustor inlet-air conditions were maintained for each altitude and engine-speed point selected at values determined from an engine-performance investigation made in the NACA Cleveland altitude wind tunnel (reference 1) at zero ram conditions (fig. 5). The required operating conditions from reference 1, the actual test conditions, and the results obtained are listed in table I. At each altitude and engine-speed point investigated, an attempt was made to obtain an average combustor-outlet temperature equal to or greater than that required for normal engine operation at that point. For each simulated engine-speed point, there was an altitude above which the required combustor-outlet-gas temperature could not be obtained. The altitude operational limits were determined for both AN-F-28 and AN-F-32 fuels. The combustion efficiencies over the range of engine operational speeds and altitudes were determined with AN-F-32 fuel.

## RESULTS

The altitude operational limits obtained using AN-F-28 and AN-F-32 fuels are shown in figures 6 and 7, respectively, where altitude is plotted against engine speed. The solid curves separate the region where the combustor-outlet temperatures obtainable were sufficient for normal operation of the can-type combustor from the region where either the combustor-outlet temperatures obtainable were insufficient for operation of the engine or where burner blow-out occurred. Figure 7(b) includes lines of constant combustion efficiency. The constant temperature-rise efficiency lines were obtained by interpolating between the data points. The altitude operational limits using AN-F-32 fuel were found to be approximately 60,000 feet for an engine speed of 6000 rpm and approximately 38,000 feet for an

engine speed of 4000 rpm (fig. 7). The results indicate that the
altitude operational limits with AN-F-32 fuel are higher over the
largest part of the engine-speed range than with AN-F-28 fuel. The
maximum difference reaches 10,000 feet; however, as the rated engine
speed (7600 rpm) is approached, the difference in limits between the
two fuels is nearly eliminated.

The variation of the combustion efficiency with altitude for
engine speeds of 4000 and 7600 rpm using AN-F-32 fuel is shown in fig-
ure 8. Combustion efficiency is defined as the ratio of the measured
total-temperature rise across the combustor to the theoretical total-
temperature rise across the combustor $\dfrac{\Delta T_m(A - B)}{\Delta T_t}$ (reference 2). A
combustion efficiency of 95 percent was obtained at rated engine speed
(7600 rpm) and an altitude of 20,000 feet. A change of altitude from
20,000 to 60,000 feet showed a 20-percent decrease in combustion effi-
ciency while the engine was operating at a speed of 7600 rpm; whereas,
at an engine speed of 4000 rpm a change of altitude from 10,000 to
40,000 feet showed a 52-percent decrease in combustion efficiency.

The effect of the variation of fuel-air ratio on combustor perform-
ance at an operating point chosen near the dead-band for AN-F-28 fuel
is shown in figure 9.

The temperature distribution at instrumentation plane B-B (fig. 1)
for a simulated engine speed of 7600 rpm and representing two simulated
altitudes (50,000 and 55,000 ft) using AN-F-32 fuel is shown in fig-
ure 10. Three temperature-distribution patterns taken at simulated
altitudes of 20,000, 50,000, and 55,000 feet and at a simulated speed
of 7600 rpm using AN-F-28 fuel are presented in figure 11.

It can be shown from the momentum equation for a constant cross-
sectional-area combustor that the total-pressure drop across the com-
bustor expressed as a fraction of impact pressure is a linear function
of the ratio of inlet-to-outlet gas densities. The impact pressure
was calculated at the inlet to the combustor assuming that the inlet
area was equal to the maximum cross-sectional area of the combustor.
When the pressure drop is related to the maximum cross-sectional area
of the combustor, useful comparisons can be made with the pressure
drop in other combustors of different geometry. Figure 12 shows total-
pressure drop expressed as a fraction of impact pressure $\Delta P/q$ plotted
against inlet-to-outlet density ratio $\rho_A/\rho_B$.

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## SUMMARY OF RESULTS

From an investigation of the performance characteristics of a can-type combustor, the following results were obtained:

1. The altitude operational limits with AN-F-32 fuel were found to be approximately 60,000 feet for an engine speed of 6000 rpm and approximately 38,000 feet for an engine speed of 4000 rpm. The results indicated that the altitude operational limits with AN-F-32 fuel are higher over the largest part of the engine-speed range than with AN-F-28 fuel.

2. A combustion efficiency of 95 percent was obtained at rated engine speed (7600 rpm) and an altitude of 20,000 feet with AN-F-32 fuel. A change of altitude from 20,000 to 60,000 feet showed a 20-percent decrease in combustion efficiency while the engine was operating at 7600 rpm; whereas, at an engine speed of 4000 rpm a change of altitude from 10,000 to 40,000 feet showed a 52-percent decrease in combustion efficiency.

Flight Propulsion Research Laboratory,
    National Advisory Committee for Aeronautics,
        Cleveland, Ohio.

## REFERENCES

1. Fleming, William A.: Altitude-Wind-Tunnel Investigation of a 4000-Pound-Thrust Axial-Flow Turbojet Engine. I - Performance and Windmilling Drag Characteristics. NACA RM No. E8F09, 1948.

2. Turner, L. Richard, and Lord, Albert M.: Thermodynamic Charts for the Computation of Combustion and Mixture Temperatures at Constant Pressure. NACA TN No. 1086, 1946.

TABLE I — SUMMARY OF STATIC PERFORMANCE DATA FOR CAN-TYPE COMBUSTOR

| Run (1) | Simulated conditions | | Required operating conditions[2] | | | | Actual test conditions and results | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Engine speed (rpm) | Altitude (ft) | Mass flow (lb/sec) | Inlet static pressure (in.Hg absolute) | Combustor-outlet average temperature (°F) | Combustor-inlet average temperature (°F) | Mass flow (lb/sec) | Inlet static pressure (in.Hg absolute) | Combustor-outlet average temperature (°F) | Fuel-air ratio | Combustor-inlet average temperature (°F) | Average temperature rise (°F) | Temperature-rise efficiency (percent) |
| 1 | 4500 | 40,000 | 1.12 | 10.5 | 620 | 39 | 1.11 | 10.4 | 420 | 0.0152 | 35 | 385 | 0.35 |
| 2 | 5000 | 40,000 | 1.29 | 12.4 | 670 | 68 | 1.30 | 12.4 | 627 | .0107 | 66 | 561 | .72 |
| 3 | 5000 | 45,000 | 1.04 | 10.0 | 670 | 67 | 1.00 | 9.7 | 616 | .0117 | 67 | 549 | .65 |
| 4 | 5500 | 45,000 | 1.20 | 11.8 | 750 | 97 | 1.24 | 11.7 | 897 | .0194 | 90 | 807 | .63 |
| 5 | 5000 | 50,000 | .82 | 7.7 | 670 | 68 | .82 | 7.5 | 579 | .0112 | 67 | 512 | .63 |
| 6 | 5500 | 50,000 | .95 | 8.9 | 750 | 97 | .96 | 8.8 | ------ | .0158 | ---- | ----- | --- |
| 7 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.05 | 10.7 | 965 | .0219 | 120 | 845 | .57 |
| 8 | 6500 | 50,000 | 1.13 | 11.4 | 1010 | 162 | 1.14 | 11.4 | 1137 | .0212 | 160 | 977 | .68 |
| 9 | 7600 | 50,000 | 1.26 | 16.9 | 1465 | 240 | 1.27 | 16.9 | 1464 | .0237 | 238 | 1226 | .78 |
| 10 | 5000 | 55,000 | .67 | 6.4 | 670 | 67 | .68 | 6.3 | 558 | .0107 | 67 | 491 | .63 |
| 11 | 6000 | 55,000 | .86 | 8.5 | 860 | 129 | .86 | 8.3 | 780 | .0170 | 132 | 648 | .54 |
| 12 | 6500 | 55,000 | .93 | 9.7 | 1010 | 162 | .93 | 9.9 | 1145 | .0223 | 162 | 983 | .65 |
| 13 | 7000 | 55,000 | .97 | 11.0 | 1180 | 196 | .98 | 10.6 | 1111 | .0210 | 196 | 915 | .64 |
| 14 | 7600 | 55,000 | 1.01 | 12.5 | 1465 | 239 | 1.04 | 12.2 | 1317 | .0246 | 240 | 1077 | .66 |
| 15 | 6000 | 60,000 | .66 | 6.8 | 860 | 130 | .68 | 6.8 | 586 | .0126 | 136 | 450 | .50 |
| 16 | 6500 | 60,000 | .71 | 7.9 | 1010 | 162 | .71 | 7.7 | 982 | .0187 | 164 | 818 | .63 |
| 17 | 7000 | 60,000 | .75 | 9.1 | 1182 | 198 | .76 | 9.1 | 1068 | .0232 | 198 | 870 | .56 |
| 18 | 4000 | 30,000 | 1.45 | 14.1 | 650 | 34 | 1.43 | 13.9 | 767 | .0166 | 35 | 732 | .62 |
| 19 | 4500 | 35,000 | 1.37 | 13.2 | 625 | 40 | 1.38 | 13.1 | 755 | .0167 | 39 | 716 | .60 |
| 20 | 7600 | 30,000 | 3.17 | 42.1 | 1440 | 262 | 3.12 | 40.0 | 1636 | .0225 | 251 | 1385 | .93 |
| 21 | 7000 | 30,000 | 2.98 | 36.0 | 1200 | 218 | 3.04 | 35.8 | 1741 | .0249 | 223 | 1518 | .93 |
| 22 | 6000 | 30,000 | 2.56 | 26.9 | 900 | 150 | 2.56 | 27.0 | 1620 | .0250 | 148 | 1472 | .89 |
| 23 | 5000 | 30,000 | 1.96 | 19.1 | 710 | 87 | 1.98 | 19.3 | 1306 | .0222 | 87 | 1219 | .81 |
| 24 | 4000 | 30,000 | 1.45 | 14.1 | 650 | 34 | 1.45 | 14.2 | 703 | .0140 | 34 | 669 | .67 |
| 25 | 4000 | 35,000 | 1.20 | 11.5 | 600 | 14 | 1.20 | 11.5 | 669 | .0139 | 14 | 655 | .66 |
| 26 | 7600 | 40,000 | 2.04 | 27.3 | 1465 | 240 | 1.98 | 26.9 | 1540 | .0223 | 242 | 1298 | .87 |
| 27 | 7000 | 40,000 | 1.94 | 23.6 | 1180 | 198 | 1.96 | 23.6 | 1581 | .0234 | 194 | 1387 | .88 |
| 28 | 6000 | 40,000 | 1.69 | 17.6 | 860 | 130 | 1.66 | 17.4 | 1303 | .0214 | 129 | 1174 | .81 |
| 29 | 5000 | 40,000 | 1.29 | 12.4 | 670 | 68 | 1.30 | 12.4 | 1115 | .0219 | 64 | 1051 | .70 |
| 30 | 4500 | 40,000 | 1.12 | 10.5 | 625 | 39 | 1.12 | 10.4 | 611 | .0124 | 28 | 583 | .65 |
| 31 | 4000 | 40,000 | .95 | 9.0 | 600 | 14 | .95 | ------ | ------ | .0208 | 14 | ----- | --- |
| 32 | 5000 | 45,000 | 1.04 | 10.0 | 670 | 67 | 1.06 | 9.9 | 656 | .0131 | 64 | 592 | .64 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 4500 | 45,000 | 0.90 | 8.5 | 625 | 39 | 0.91 | 8.6 | 753 | 0.0181 | 44 | 709 | 0.56 |
| 34 | 7600 | 50,000 | 1.26 | 16.9 | 1465 | 240 | 1.26 | 16.9 | 1559 | .0268 | 240 | 1319 | .76 |
| 35 | 7000 | 50,000 | 1.20 | 14.6 | 1180 | 198 | 1.18 | 14.4 | 1172 | .0203 | 203 | 969 | .71 |
| 36 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.00 | 9.9 | 1177 | .0236 | 125 | 1052 | .67 |
| 37 | 5000 | 50,000 | .82 | 7.7 | 670 | 68 | .83 | 7.6 | 794 | .0208 | 68 | 726 | .52 |
| 38 | 4500 | 50,000 | .69 | 6.6 | 625 | 39 | .69 | 6.6 | ---- | ---- | 39 | ---- | ---- |
| 39 | 5000 | 55,000 | .67 | 6.4 | 670 | 67 | .67 | 6.2 | 627 | .0193 | 68 | 553 | .42 |
| 40 | 7600 | 60,000 | .76 | 10.5 | 1465 | 240 | .76 | 10.5 | 1333 | .0260 | 240 | 1093 | .65 |
| 41 | 7000 | 60,000 | .75 | 9.1 | 1180 | 198 | .75 | 9.2 | 1139 | .0248 | 195 | 944 | .58 |
| 42 | 6000 | 60,000 | .66 | 6.8 | 860 | 130 | .66 | 6.9 | 1005 | .0239 | 130 | 875 | .55 |
| 43 | 5000 | 60,000 | .50 | 4.8 | 670 | 68 | .51 | 4.8 | 612 | .0218 | 76 | 536 | .36 |
| 44 | 4000 | 20,000 | 2.02 | 21.0 | 740 | 67 | 2.02 | 20.7 | 779 | .0132 | 76 | 703 | .76 |
| 45 | 3000 | 20,000 | 1.46 | 17.1 | 750 | 28 | 1.46 | 16.9 | 777 | .0146 | 22 | 755 | .72 |
| 46 | 5500 | 60,000 | .59 | 5.7 | 750 | 97 | .60 | 5.7 | ---- | .0119 | 102 | ---- | ---- |
| 47 | 5500 | 55,000 | .80 | 7.3 | 750 | 97 | .80 | 7.3 | 692 | .0174 | 100 | 592 | .49 |
| 48 | 7000 | 55,000 | .97 | 11.0 | 1180 | 197 | .98 | 10.9 | 1133 | .0220 | 198 | 1035 | .71 |
| 49 | 7600 | 55,000 | 1.04 | 12.6 | 1465 | 239 | 1.05 | 12.6 | 1375 | .0259 | 243 | 1132 | .67 |
| 50 | 4000 | 25,000 | 1.76 | 17.4 | 700 | 50 | 1.77 | 17.3 | 690 | .0129 | 49 | 641 | .70 |
| 51 | 4000 | 15,000 | 2.38 | 24.9 | 780 | 83 | 2.39 | 24.8 | 752 | .0113 | 82 | 670 | .83 |
| 52 | 4000 | 10,000 | 2.78 | 29.1 | 840 | 99 | 2.79 | 29.1 | 837 | .0119 | 94 | 743 | .88 |
| 53 | 4000 | 40,000 | .95 | 9.0 | 600 | 14 | .98 | 8.7 | 495 | .0168 | 14 | 481 | .41 |
| 54 | 4000 | 35,000 | 1.18 | 11.6 | 600 | 14 | 1.18 | 11.5 | 614 | .0162 | 13 | 601 | .52 |
| 55 | 4000 | 30,000 | 1.45 | 14.1 | 650 | 34 | 1.44 | 13.9 | 679 | .0154 | 34 | 645 | .59 |
| 56 | 4000 | 20,000 | 2.02 | 21.0 | 740 | 67 | 2.03 | 20.9 | 778 | .0121 | 68 | 710 | .82 |
| 57 | 7600 | 60,000 | .76 | 10.5 | 1465 | 240 | .77 | 10.4 | 1412 | .0234 | 242 | 1170 | .76 |
| 58 | 7600 | 55,000 | 1.00 | 12.4 | 1465 | 240 | 1.00 | 12.5 | 1500 | .0265 | 240 | 1260 | .73 |
| 59 | 7600 | 50,000 | 1.26 | 16.9 | 1465 | 240 | 1.27 | 16.8 | 1490 | .0242 | 238 | 1252 | .79 |
| 60 | 7600 | 45,000 | 1.63 | 20.7 | 1465 | 240 | 1.64 | 20.8 | 1506 | .0235 | 238 | 1268 | .82 |
| 61 | 7600 | 40,000 | 2.04 | 27.3 | 1465 | 240 | 2.05 | 27.1 | 1476 | .0209 | 239 | 1237 | .88 |
| 62 | 7600 | 35,000 | 2.59 | 34.6 | 1465 | 240 | 2.60 | 34.7 | 1489 | .0207 | 242 | 1247 | .90 |
| 63 | 7600 | 30,000 | 3.17 | 42.1 | 1440 | 262 | 3.15 | 42.0 | 1383 | .0191 | 260 | 1123 | .87 |
| 64 | 7600 | 25,000 | 3.86 | 51.2 | 1460 | 278 | 3.89 | 50.5 | 1433 | .0195 | 279 | 1154 | .88 |
| 65 | 7600 | 20,000 | 4.57 | 60.6 | 1475 | 299 | 4.57 | 60.4 | 1454 | .0180 | 299 | 1155 | .95 |
| 66 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.06 | 10.9 | 920 | .0159 | 131 | 789 | .70 |
| 67 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.07 | 11.0 | 997 | .0191 | 131 | 866 | .65 |
| 68 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.05 | 10.9 | 1097 | .0232 | 132 | 965 | .61 |
| 69 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.06 | 10.7 | 1176 | .0252 | 130 | 1046 | .62 |
| 70 | 6000 | 50,000 | 1.05 | 10.9 | 860 | 130 | 1.05 | 10.9 | ---- | .0263 | 130 | ---- | ---- |
| 71 | 3500 | 30,000 | 1.11 | 8.0 | 650 | 11 | 1.11 | 8.0 | 437 | .0189 | 12 | 1125 | .32 |
| 72 | 6500 | 60,000 | .71 | 7.9 | 1010 | 162 | .73 | 7.8 | 1096 | .0220 | 163 | 933 | .64 |
| 73 | 6000 | 50,000 | 1.06 | 10.9 | 860 | 131 | 1.06 | 11.0 | 586 | .0095 | 131 | 455 | .66 |
| 74 | 6000 | 50,000 | 1.06 | 10.9 | 860 | 132 | 1.06 | 11.0 | 796 | .0122 | 132 | 664 | .75 |

[1] Runs 1-19, 66-70, 73, and 74 with AN-F-28 fuel; other runs with AN-F-32 fuel.
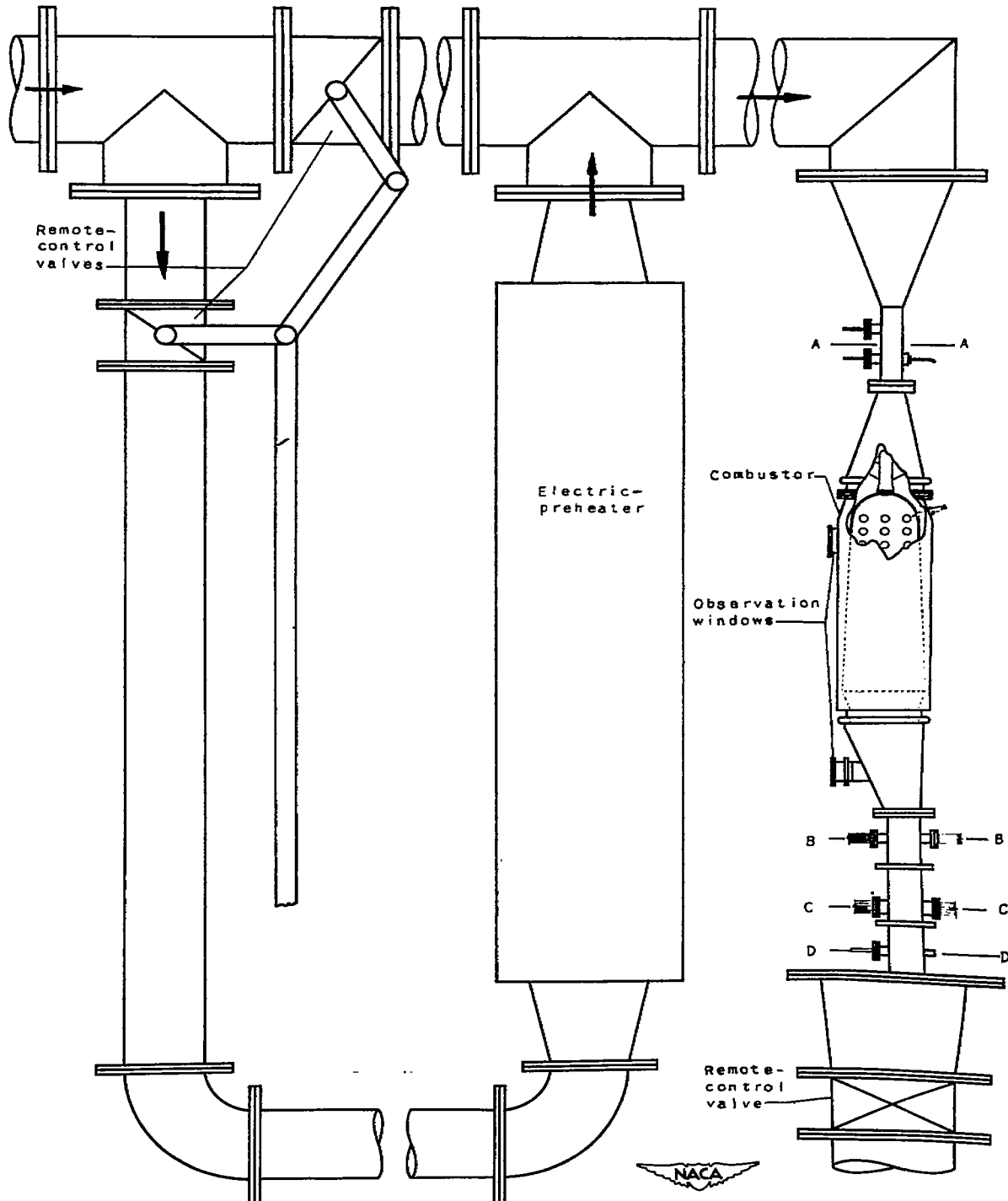[2] From Cleveland altitude-wind-tunnel investigation, reference 1.

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Figure 1. - Schematic diagram showing test rig and instrumentation positions used in investigation of can-type combustor.
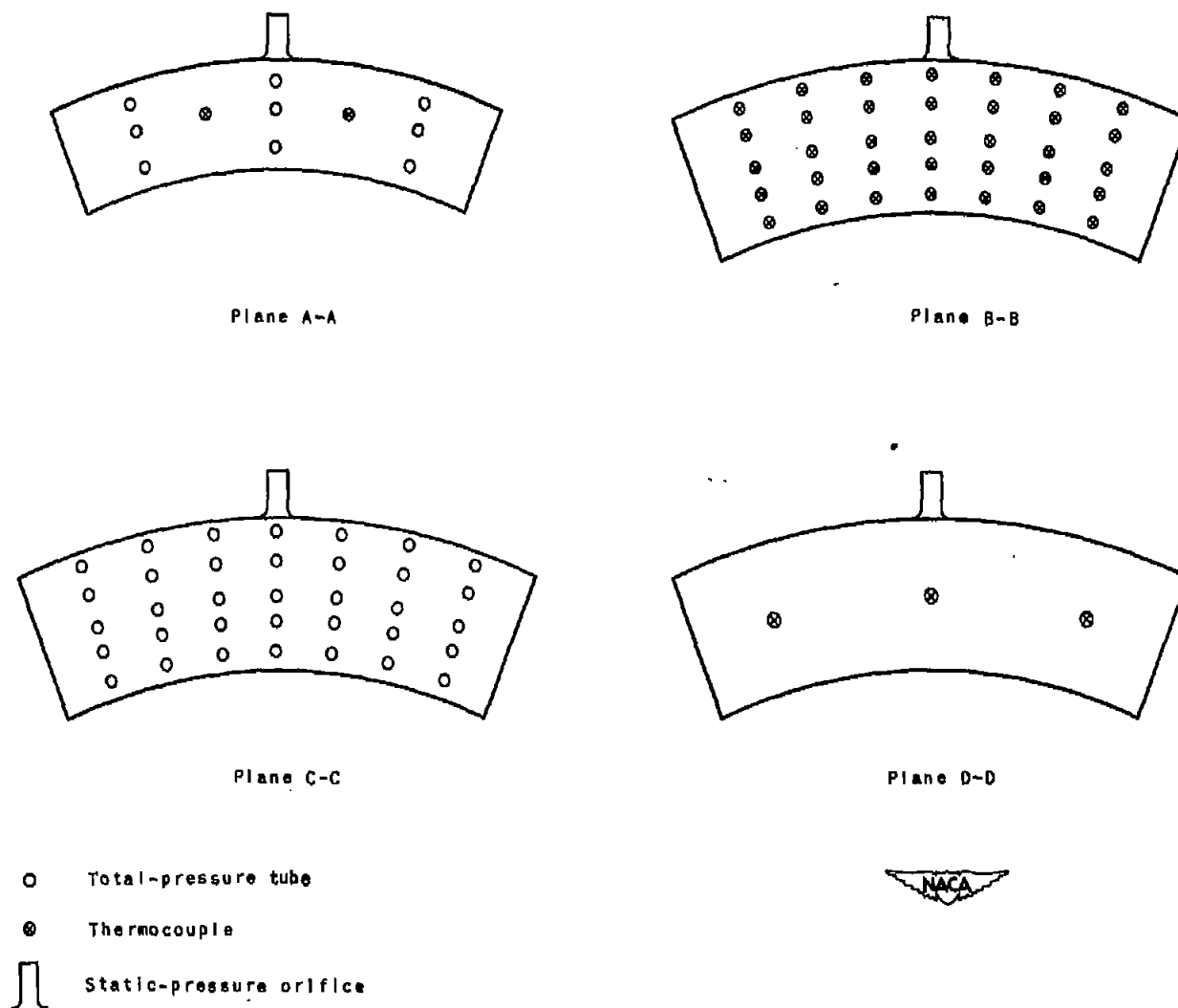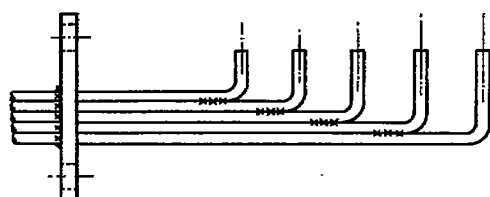
Plane A~A

Plane B-B

Plane C-C

Plane D~D

O    Total-pressure tube

⊗    Thermocouple

∏    Static-pressure orifice
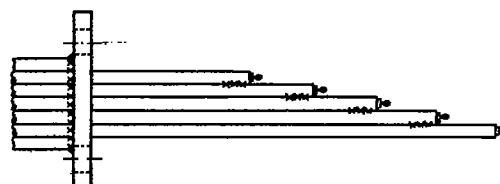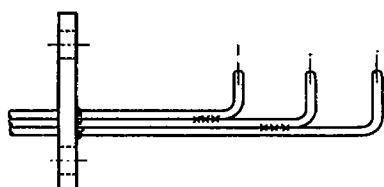
Figure 2. — Location of instruments at several instrumentation planes.

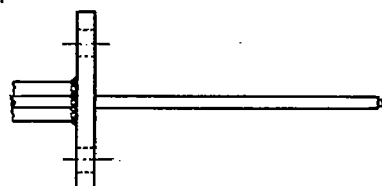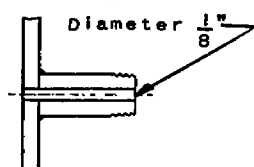Five-tube total-pressure
rake

Five-thermocouple rake

Three-tube total-pressure
rake

One-thermocouple rake

Diameter $\frac{1}{8}''$

Static-pressure connection

Figure 3. - Instrumentation details.

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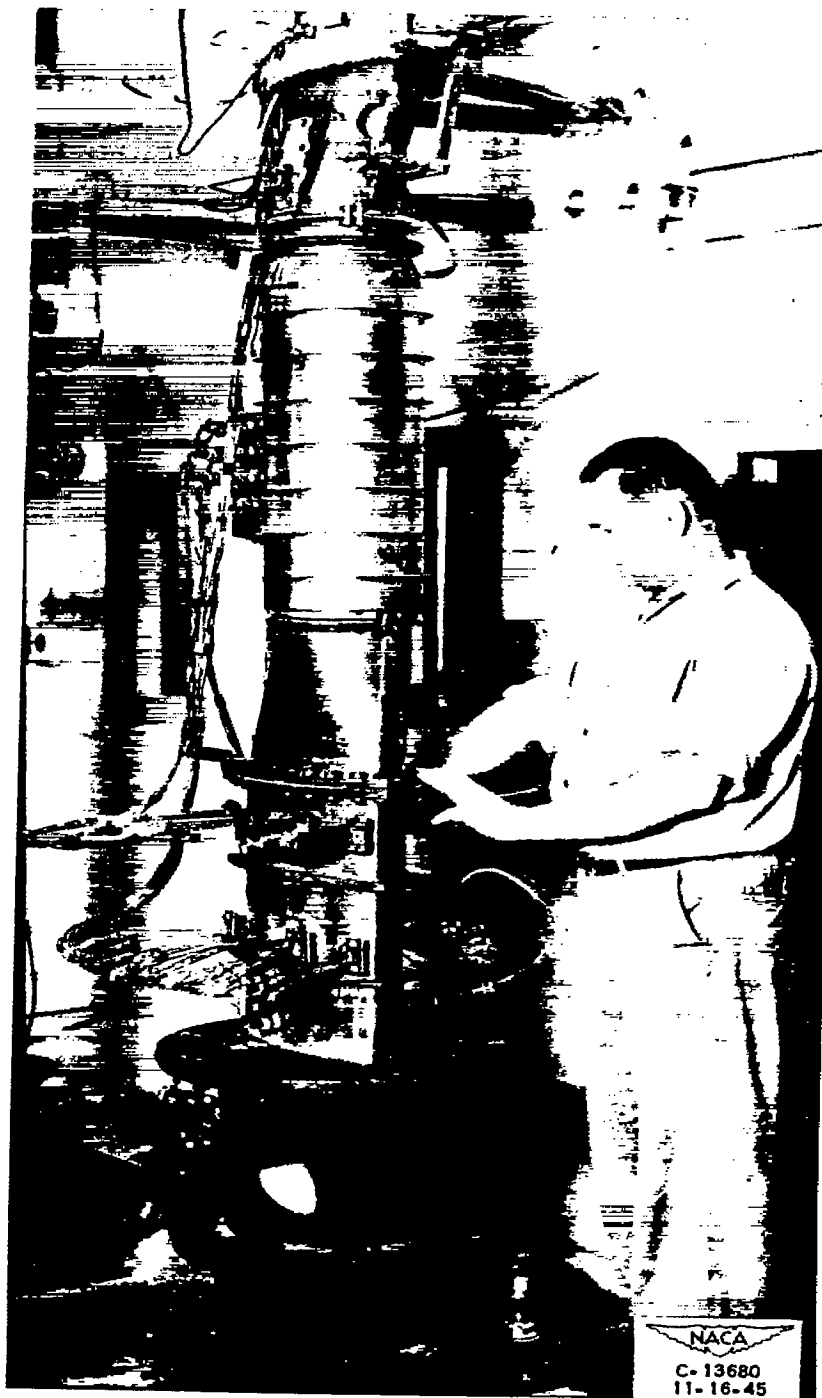


Figure 4. - Photograph of test rig, showing instrumentation positions.

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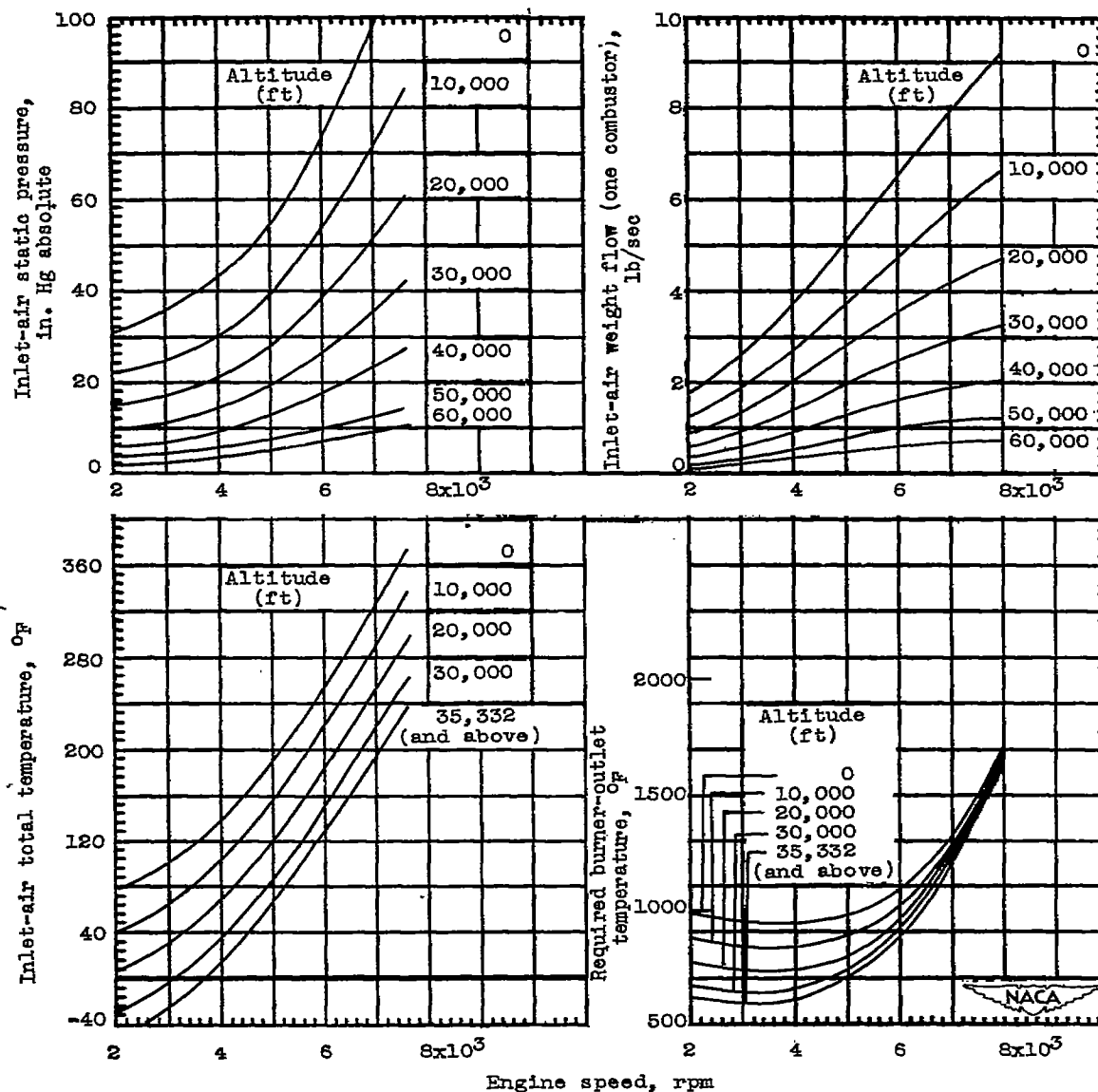


Figure 5. - Combustor inlet-air conditions and required temperature rise. Nozzle diameter, $16\frac{3}{4}$ inches; zero ram. (Data from Cleveland altitude-wind-tunnel investigation, reference 1.)
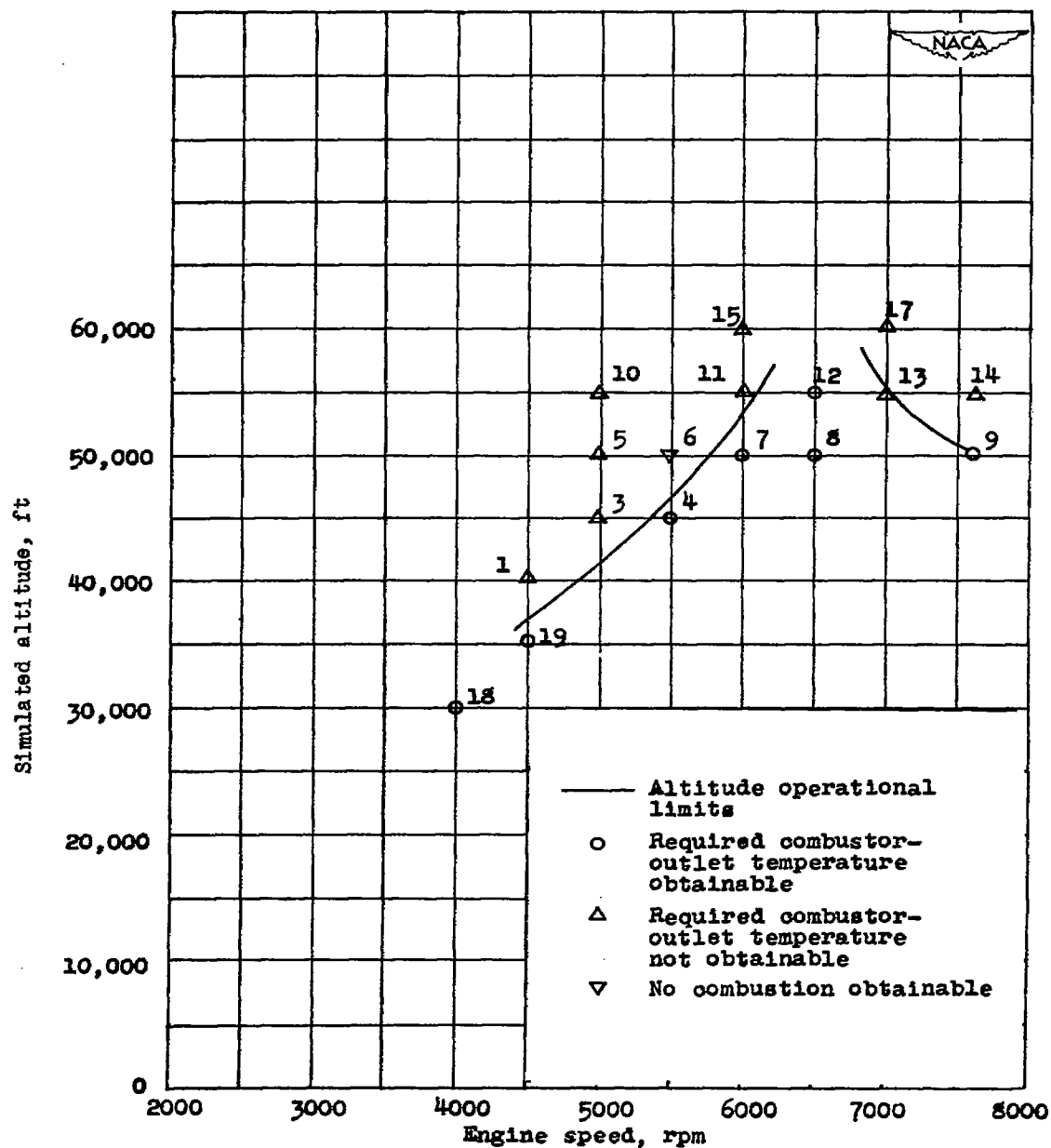
Figure 6. — Altitude operational limits for can-type combustor using AN-F-28 fuel. Zero ram. (Numbers refer to run numbers in table I.)

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(a)  Runs. (Numbers refer to run numbers in table I.)
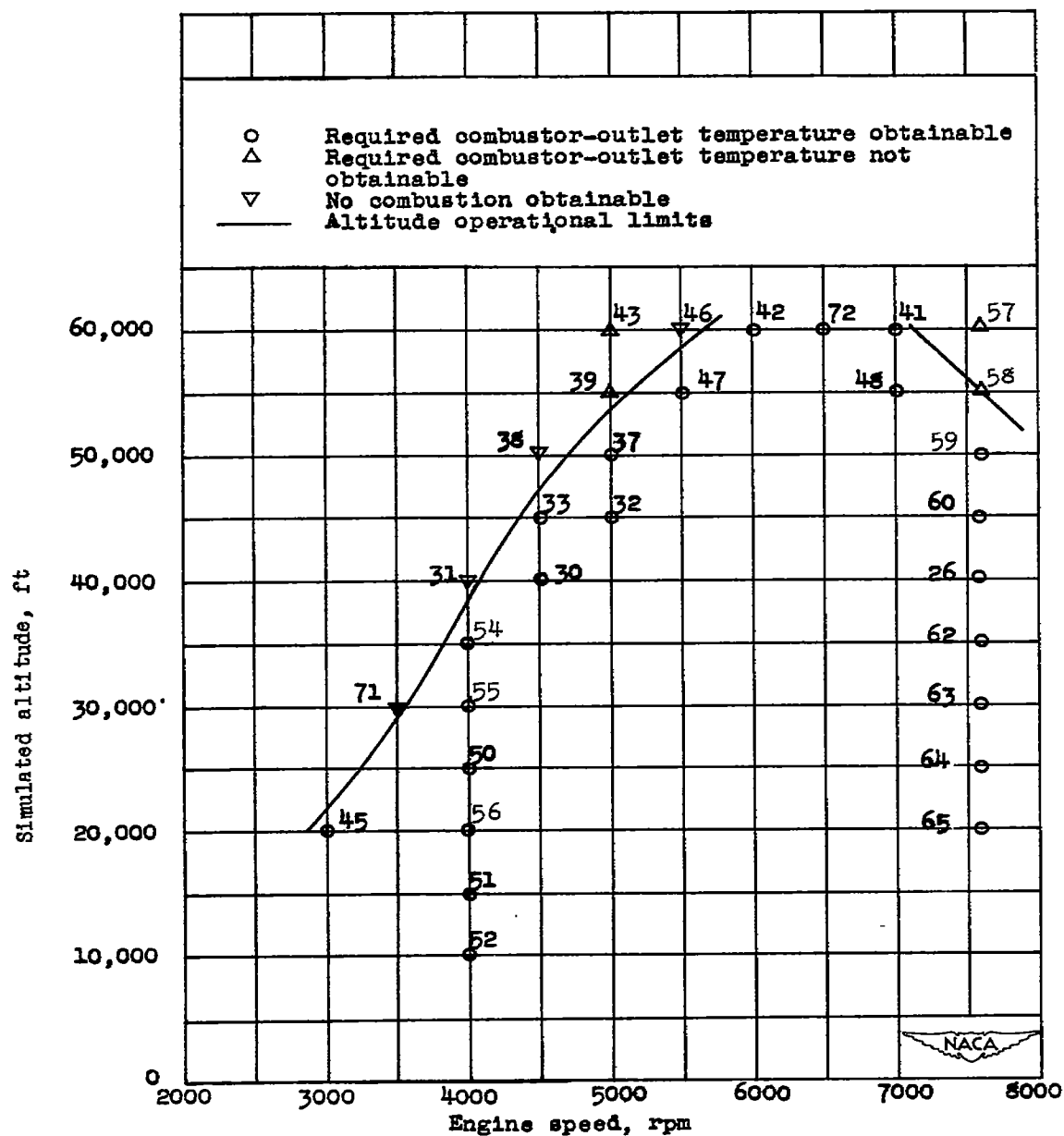
Figure 7. — Altitude operational limits for can-type combustor using
AN-F-32 fuel.  Zero ram.
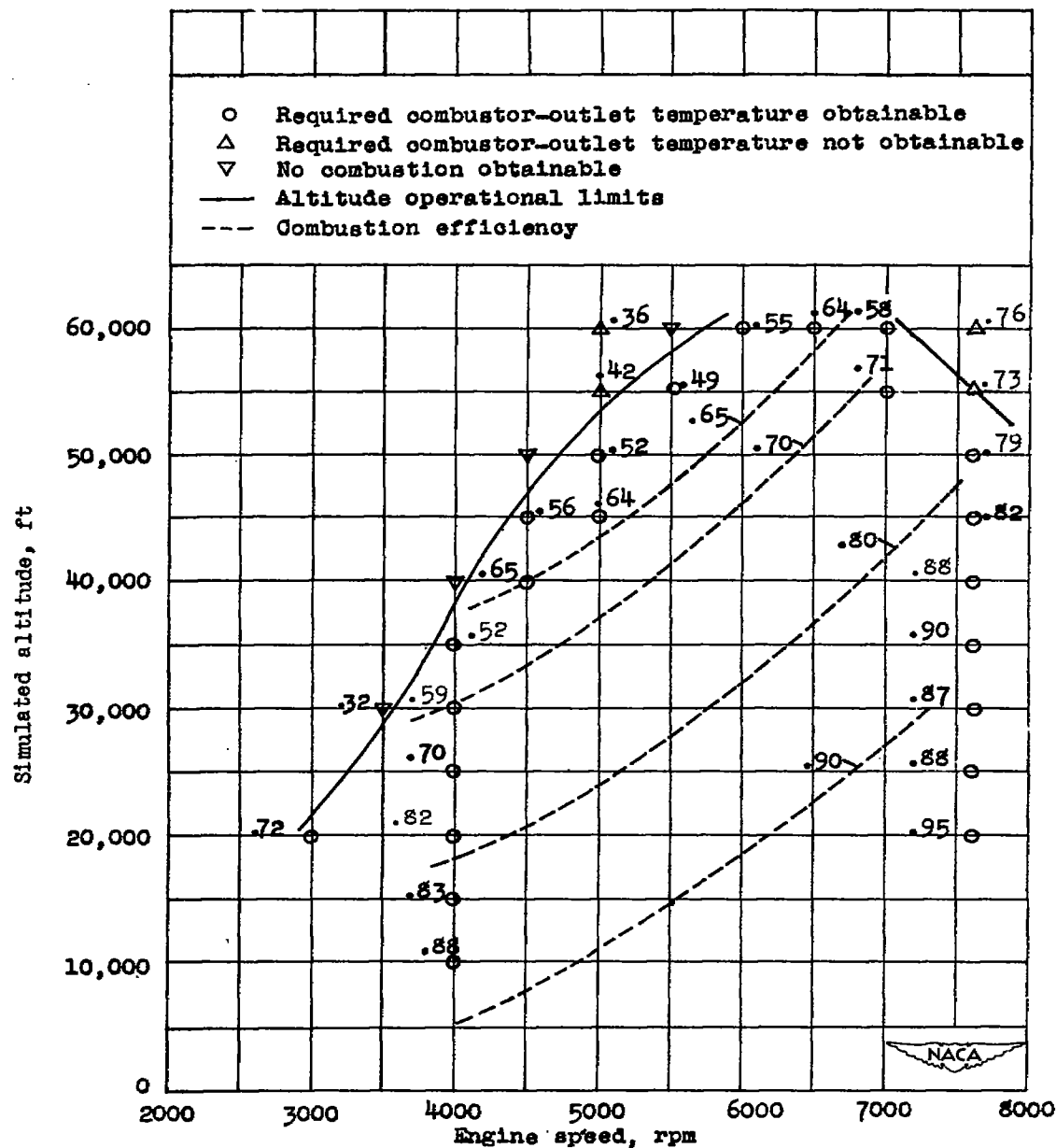
(b)   Combustion efficiencies.   (Numbers refer to combustion efficiencies.)

Figure 7. — Concluded.   Altitude operational limits for can-type combustor using AN-F-32 fuel.   Zero ram.
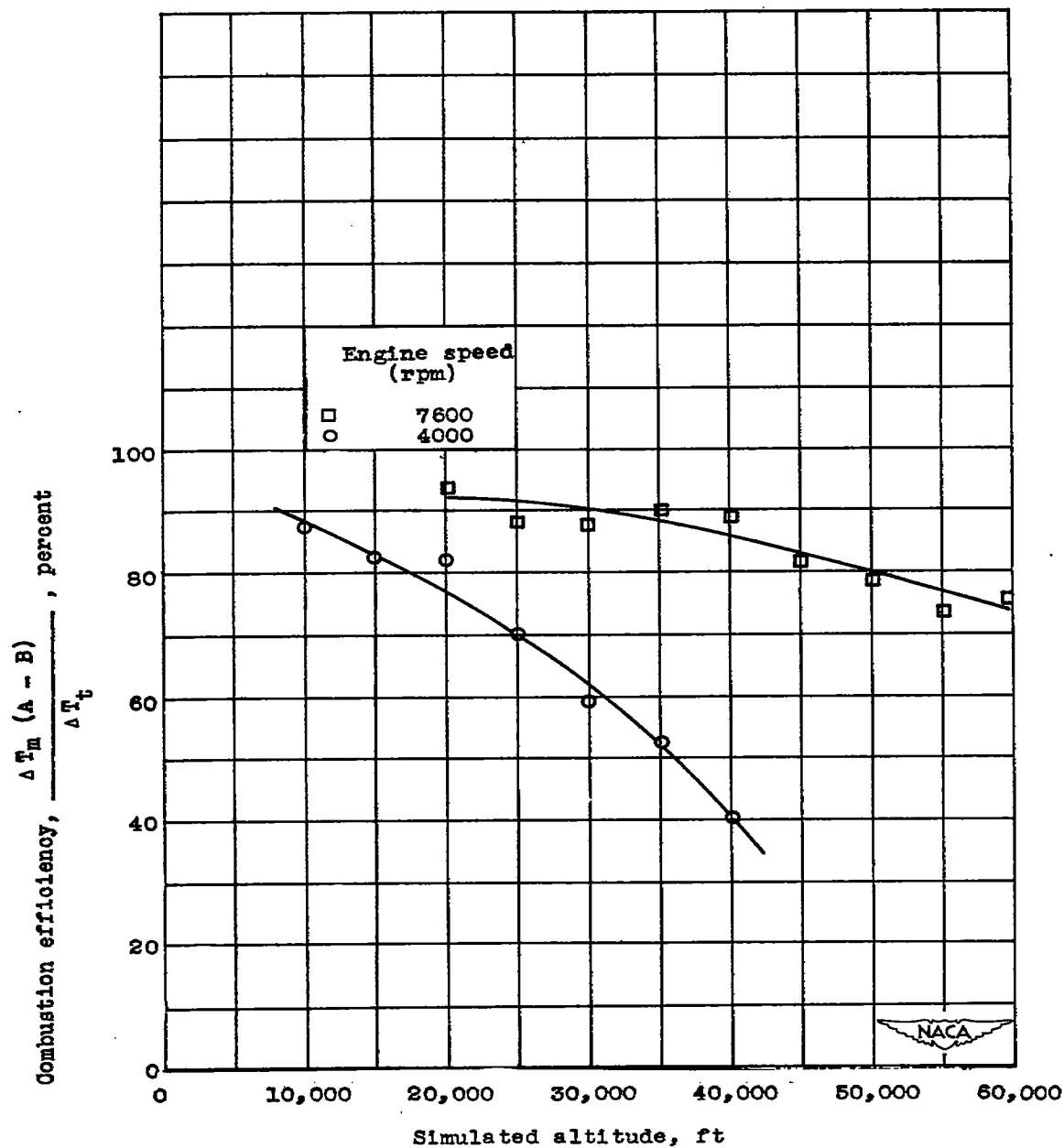
Figure 8. — Effect of variation of altitude on combustion efficiency in can-type combustor using AN-F-32 fuel. Zero ram.
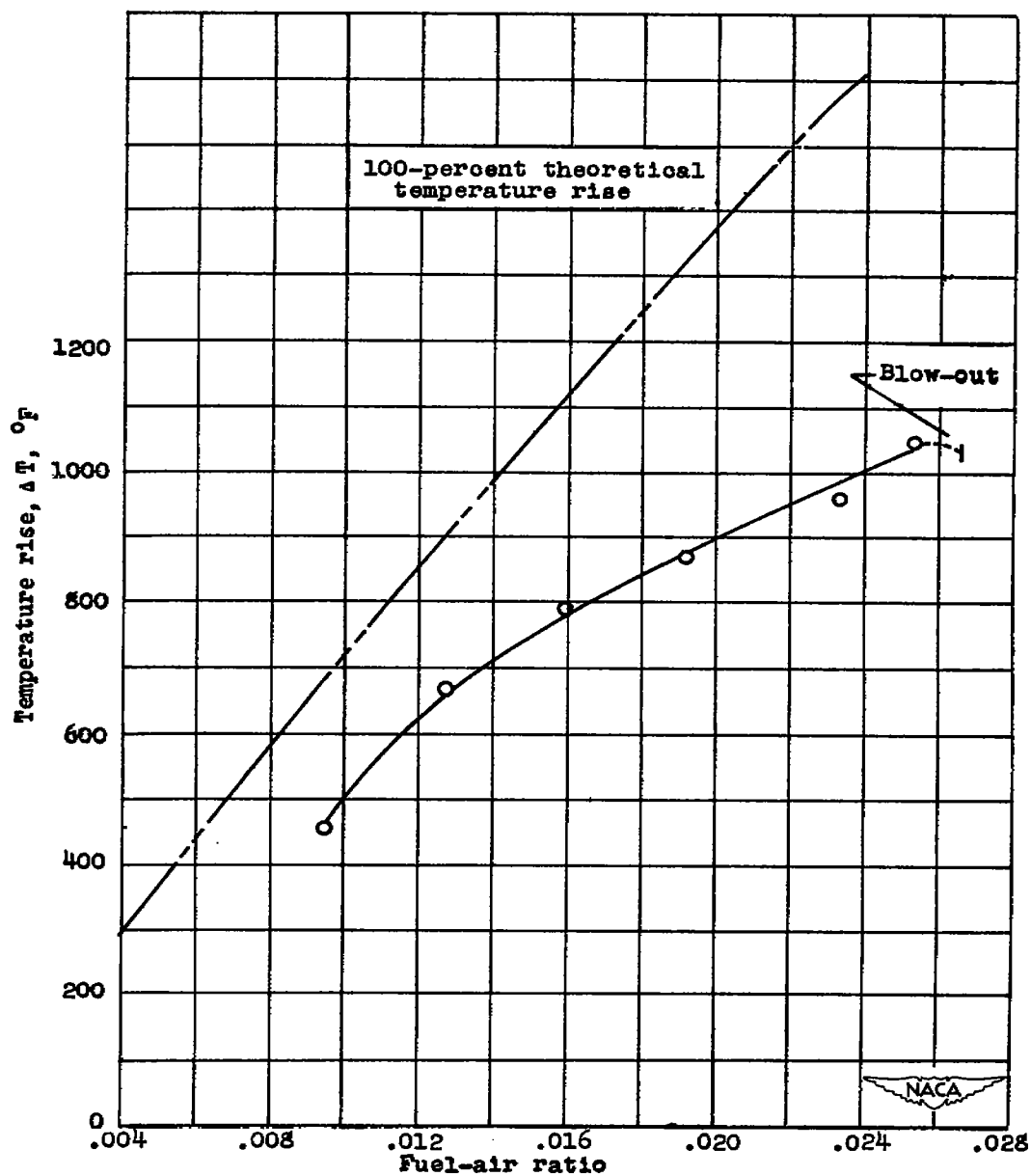
Figure 9. - Effect of variation of fuel-air ratio on temperature
rise at operating conditions near dead-band in can-type combustor.
Fuel, AN-F-28; engine speed, 6000 rpm; simulated altitude,
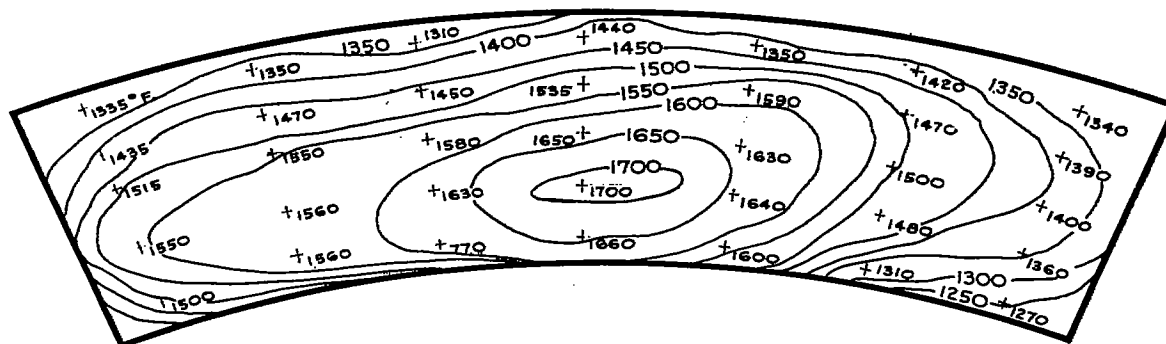50,000 feet.
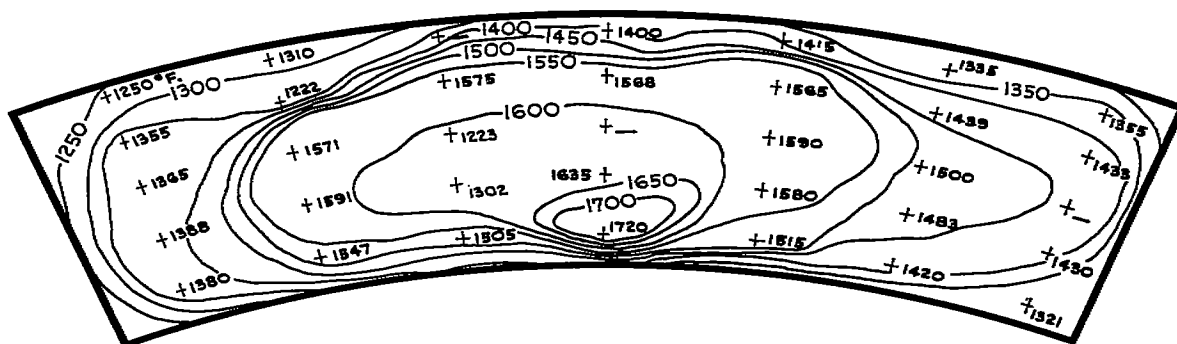
(a)  Simulated altitude, 55,000 feet.
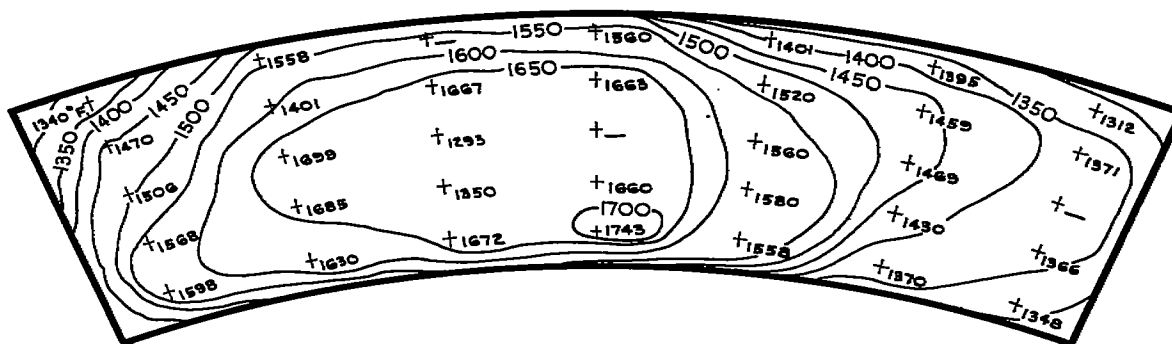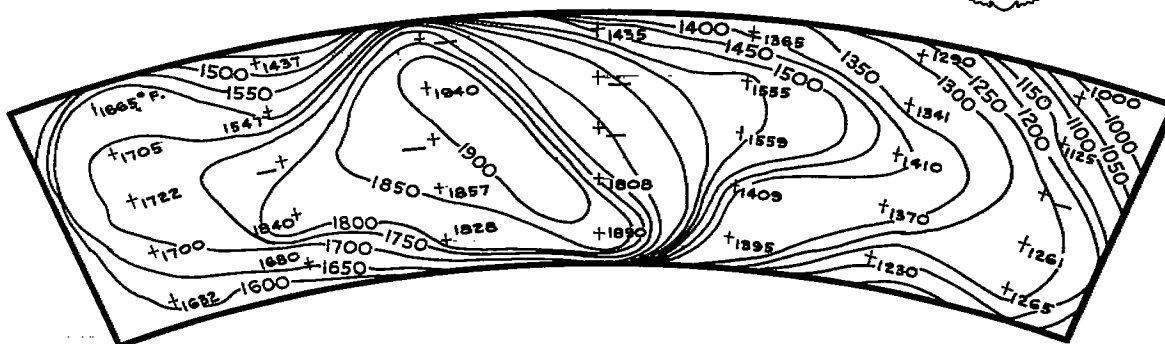
(b)  Simulated altitude, 50,000 feet.

Figure 10. - Temperature-distribution pattern at instrumentation plane B-B in can-type
combustor using AN-F-32 fuel.  Engine speed, 7600 rpm.
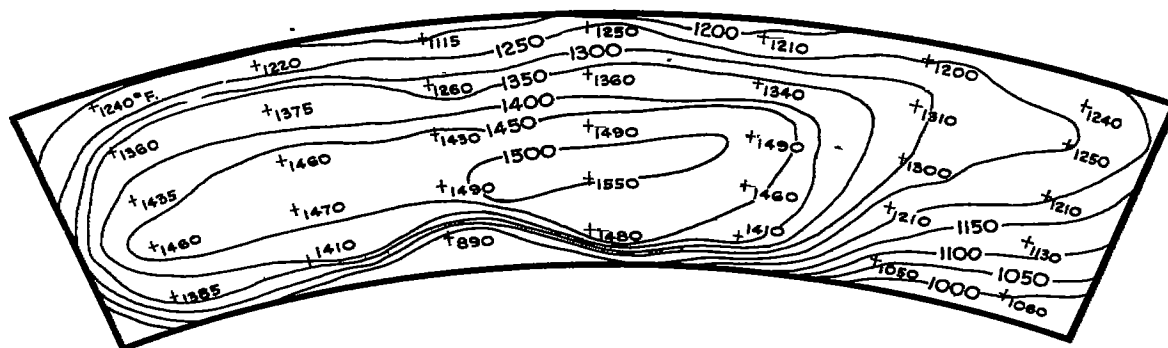
(a)  Simulated altitude, 55,000 feet.

(b)  Simulated altitude, 50,000 feet.

(c)  Simulated altitude, 20,000 feet.

Figure 11. - Temperature-distribution pattern at instrumentation plane B-B in can-type
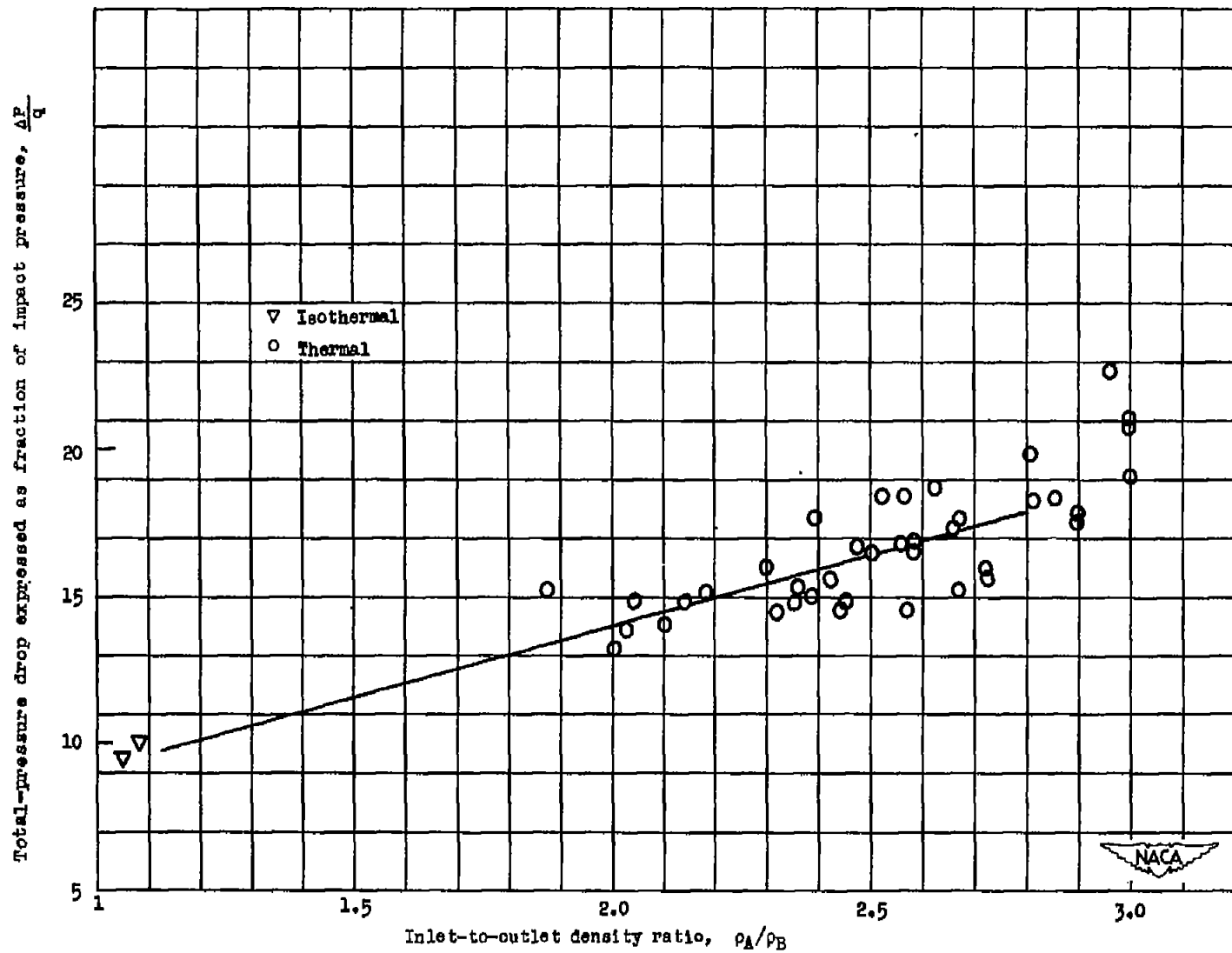combustor using AN-F-28 fuel.  Engine speed, 7600 rpm.

Figure 12. – Total-pressure drop across can-type combustor expressed as fraction of impact pressure plotted against inlet-to-outlet density ratio.